An overview of the nEXO experiment

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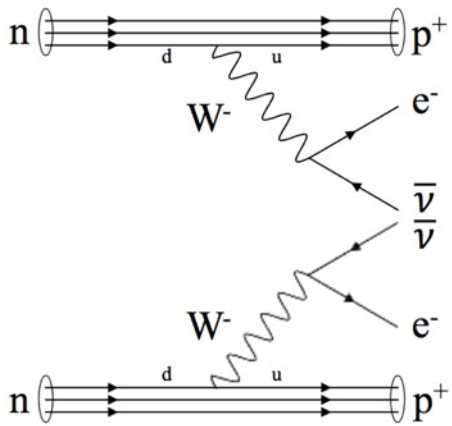
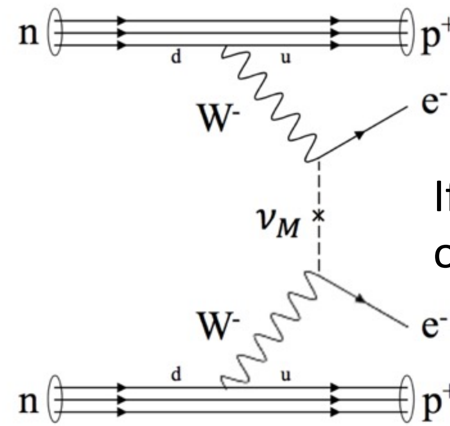
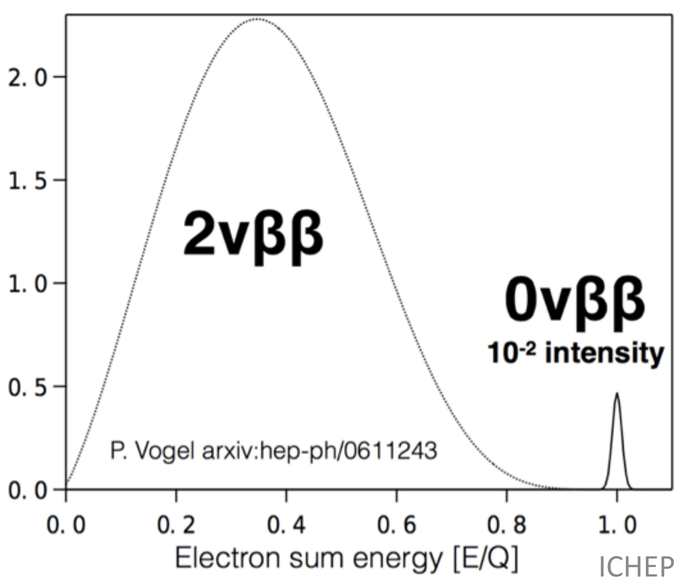
ICHEP 2022, Bologna Italy

Neutrino-less double beta decay





If neutrino is its own antiparticle



Search for neutrino-less double beta decay helps to probe:

- **If neutrino is Dirac/Majorana.**
- **Origin of neutrino mass**
- **Lepton number violation**


nEXO
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Carleton UNIVERSITY
McGill
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UMass Amherst
Yale University
BROOKHAVEN NATIONAL LABORATORY
FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
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THE UNIVERSITY OF ALABAMA 1831
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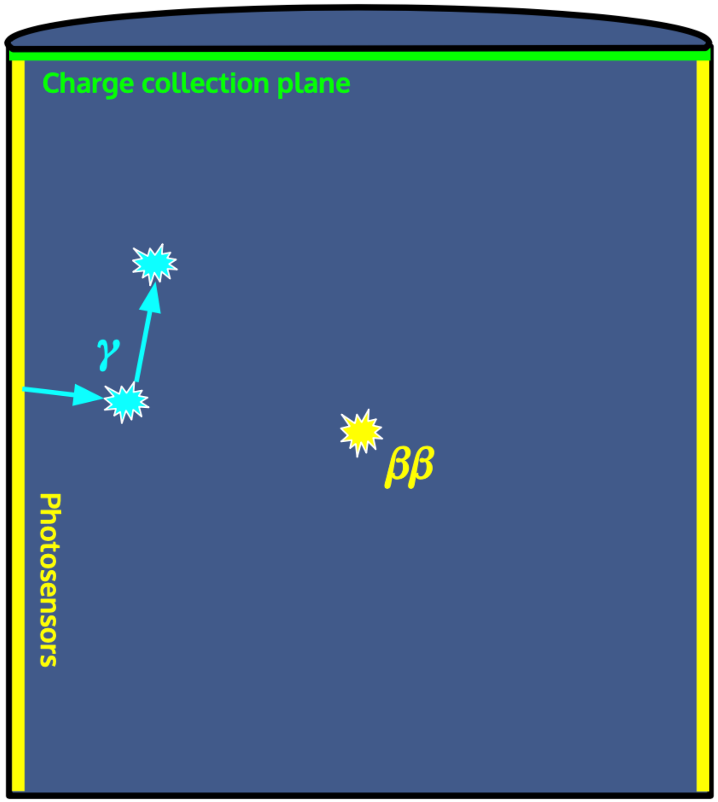
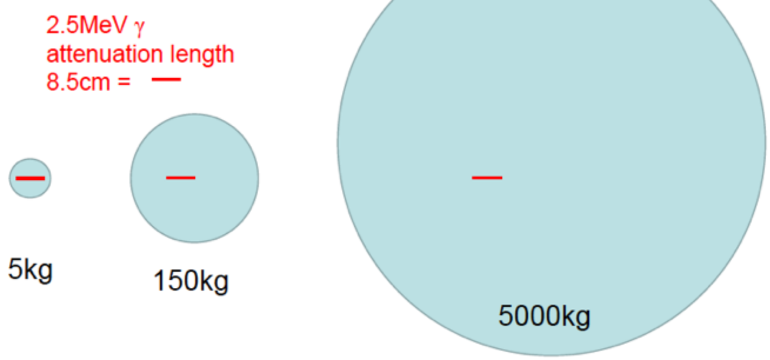
Search for $0\nu\beta\beta$ decay with liquid xenon TPC



Credit: Brian Lenardo

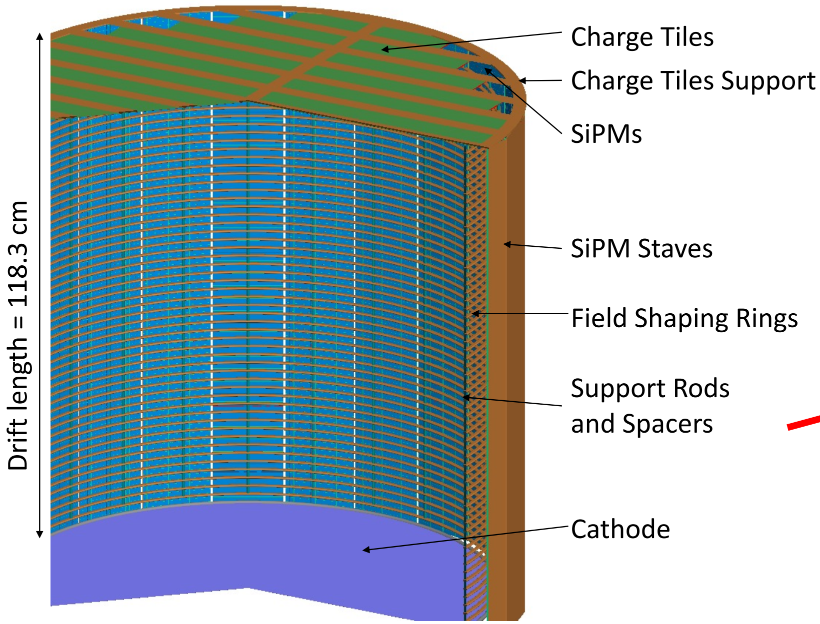
- **Proved technology in EXO-200.**
- **Scalable enriched liquid xenon (LXe).**
- **Low radioactivity in LXe and strong self-shielding.**
- **Good energy resolution (<1%) at Q value of 2.5 MeV.**
- **2D readout of ionization charge and scintillation light to achieve full 3D event reconstruction.**
- **Powerful background rejection.**

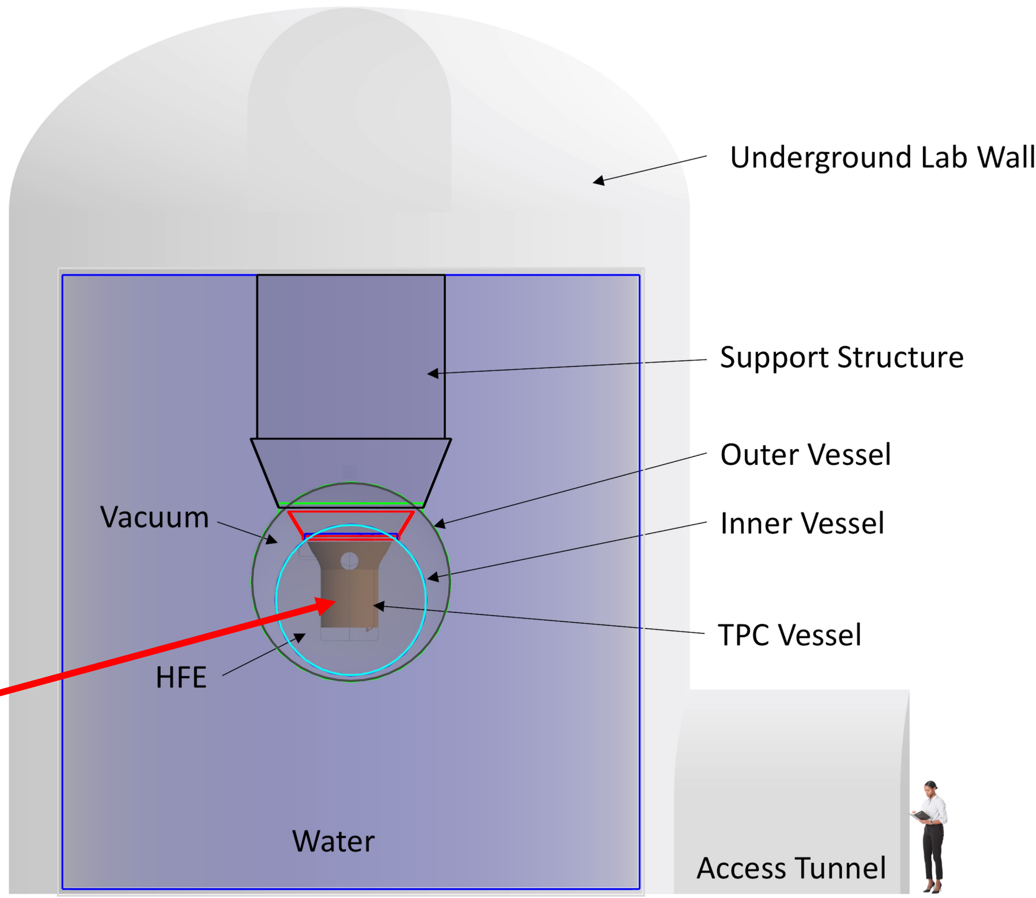
LXe mass (kg)	Diameter or length (cm)
5000	130
150	40
5	13



nEXO experiment

- **Monolithic TPC with 5 tons of 90% enriched ^{136}Xe.**
- **Located at Cryopit at SNOLAB with ~2000 m overburden.**
- **Active water Cherenkov muon veto.**

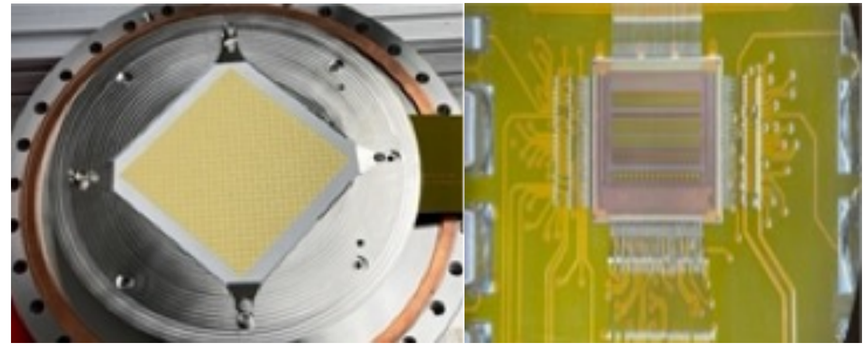


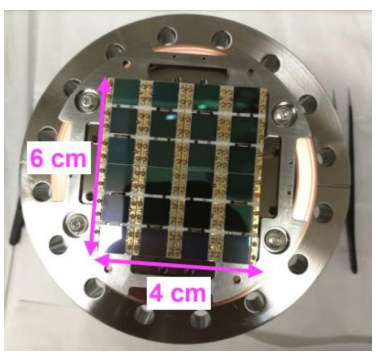


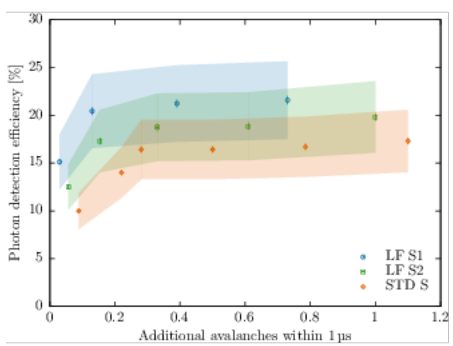
nEXO TPC design

- **Charge detection: anode plane of modular charge tiles (10 cm long and 6 mm pitch), readout with ASIC in LXe.**
- **Light detection: 4.5 m^2 of VUV SiPMs with ASIC readout in LXe.**
- **Electron lifetime: 10 ms**
- **Electric field: 400 V/cm**

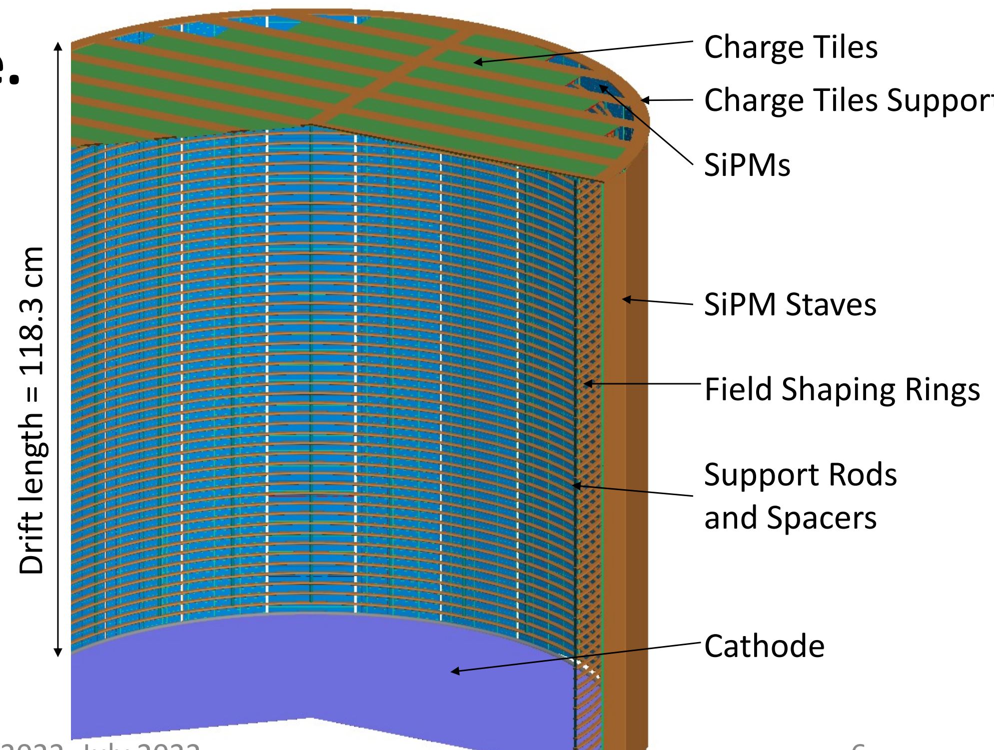
Charge sensing tile and in-LXe cold electronics







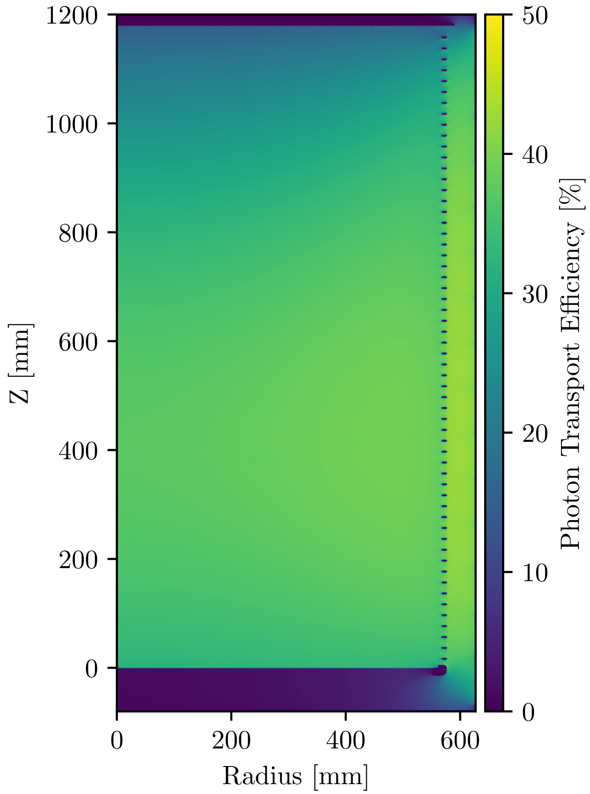
VUV silicon photomultipliers (SiPMs)



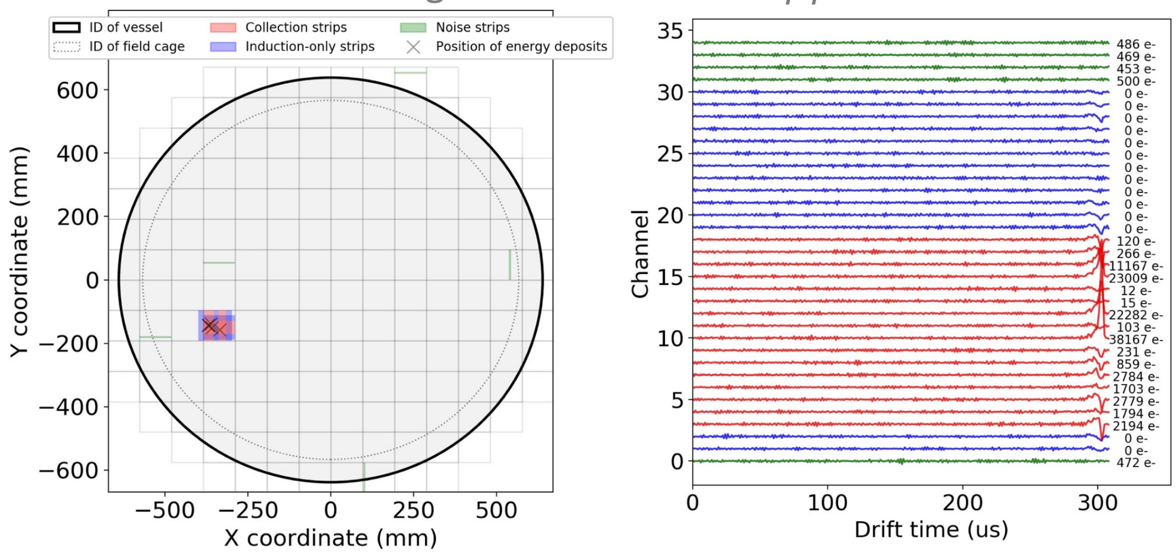
Readout simulations

- **Simulation of charge propagation in LXe based on measurements.**
- **Charge readout modeled at the waveform level.**
- **Full noise simulation of ASIC readout.**

- Z. Li et al. (NEXO) JINST **14** (2019)



Charge simulation of a $0\nu\beta\beta$ event

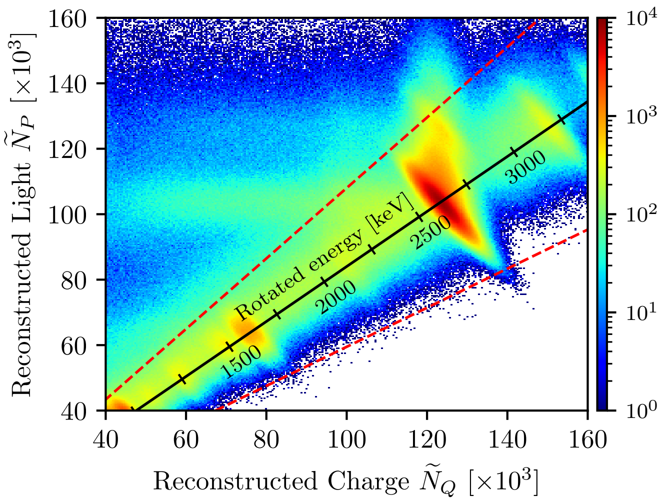


- **Light collection modeling with new data and GPU-based Chroma software**.
  - P. Nakarmi et al. (NEXO) *JINST* **15** (2020)
  - G. Gallina et al. (NEXO) *NIMA* **940** (2019)
  - A. Jamil et al. (NEXO) *IEEE TNS* **65** (2018)
  - P. Lv et al. (NEXO) *IEEE TNS* **67** (2020)
  - M. Wagenpfeil et al. (NEXO) *JINST* **16** (2021)

Event reconstruction and background rejection

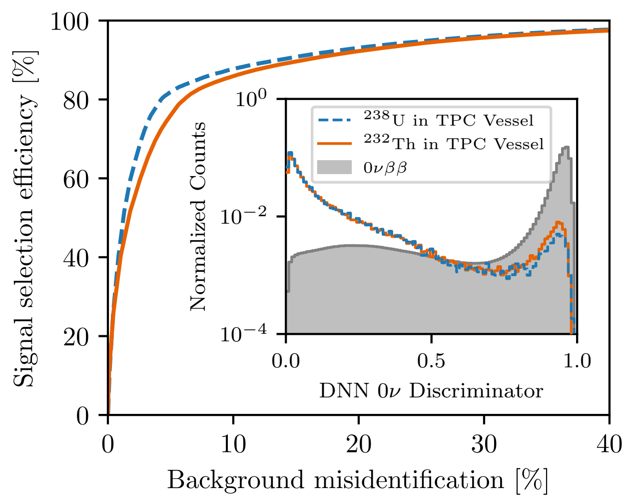
Energy

Simulated ^{232}Th background



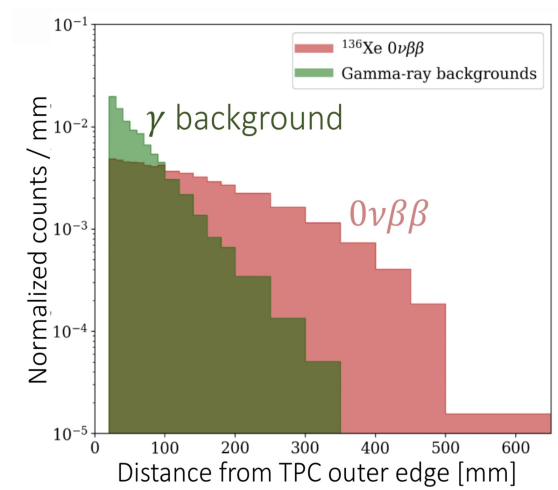
Reconstructed as sum of scintillation photons and ionization electrons

DNN-based discriminator



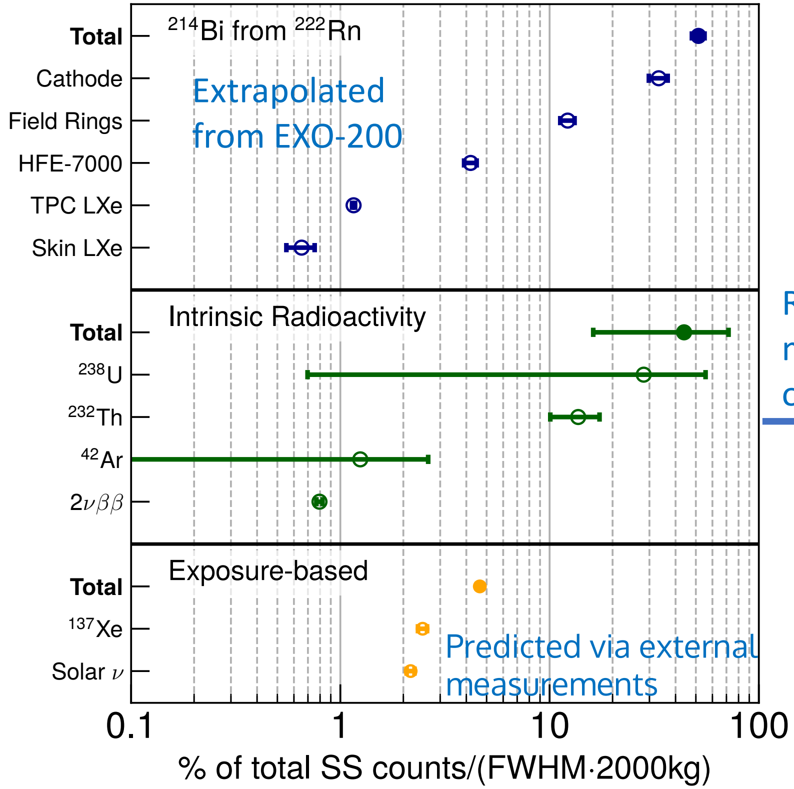
A deep neural network is trained to distinguish single-site ($\beta\beta$-like) and multi-site (γ-like) events using charge readout waveforms.

Standoff distance

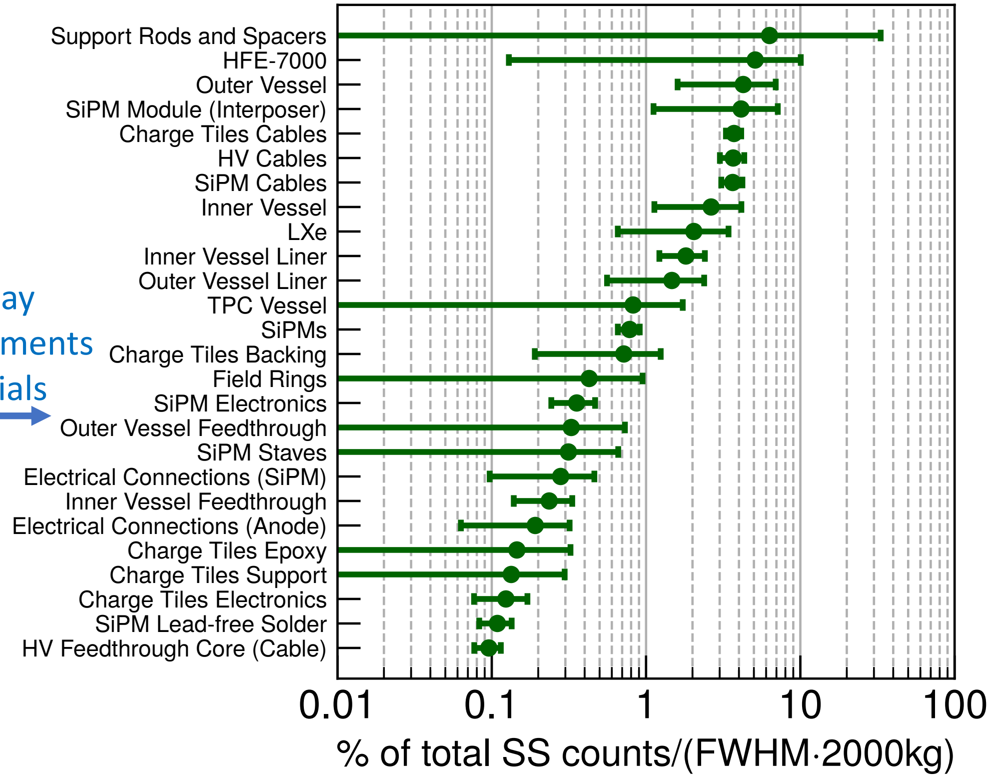


Most of background events originate from outside the fidicual volume.
ββ **events are uniformly distributed in LXe.**

Data-driven background modeling



Radioassay measurements of materials



Multi-variable analysis

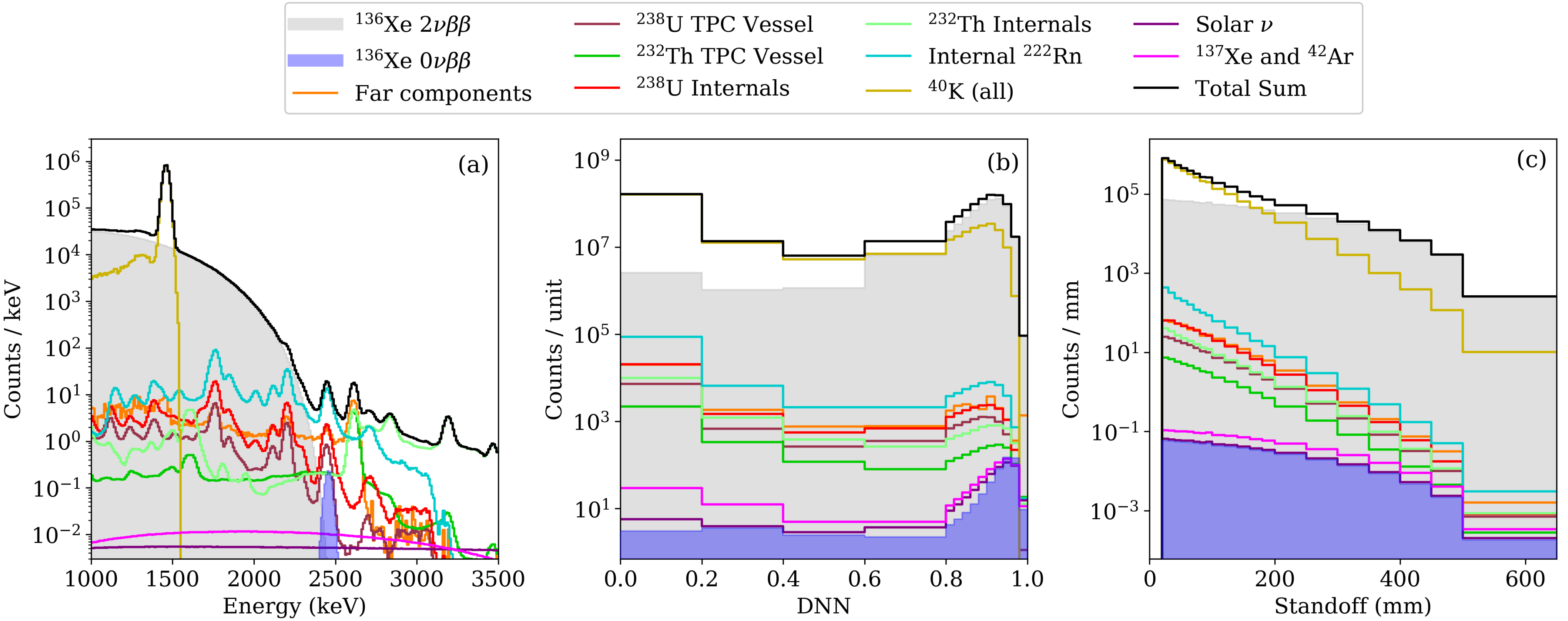
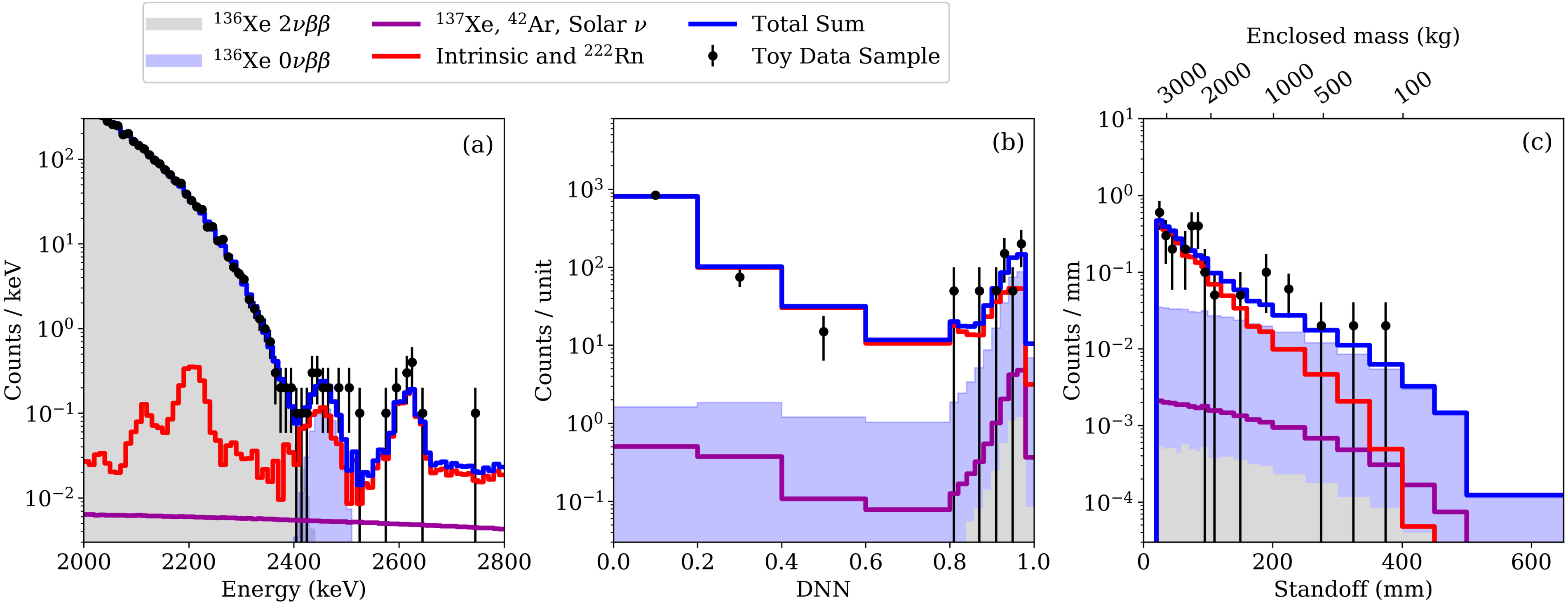


Illustration of a simulated dataset with a 3σ discovery ($T_{1/2}$ = 0.74 x 10^{28} yrs)

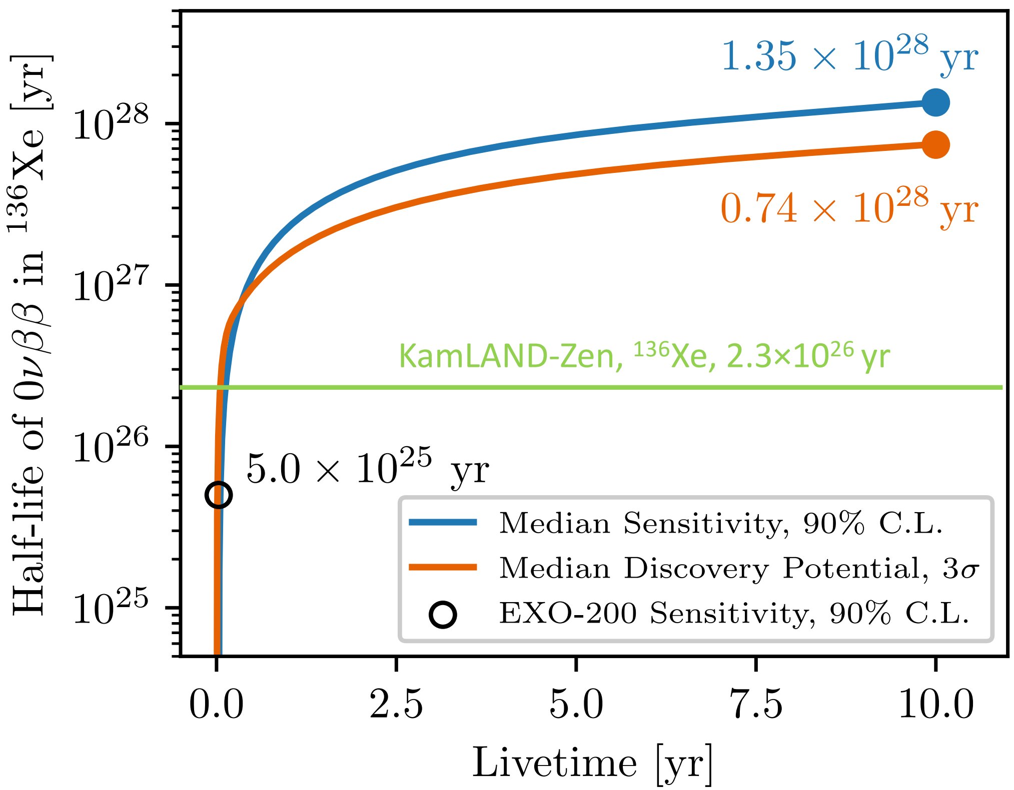
Event distribution in region of interest (ROI)

nEXO's ROI is defined as:

- Energy within $0\nu\beta\beta$ FWHM
- DNN > 0.85 ("single-site" events)
- Innermost 2 tonnes of LXe (cut on standoff)



Projected $0\nu\beta\beta$ halflife sensitivity



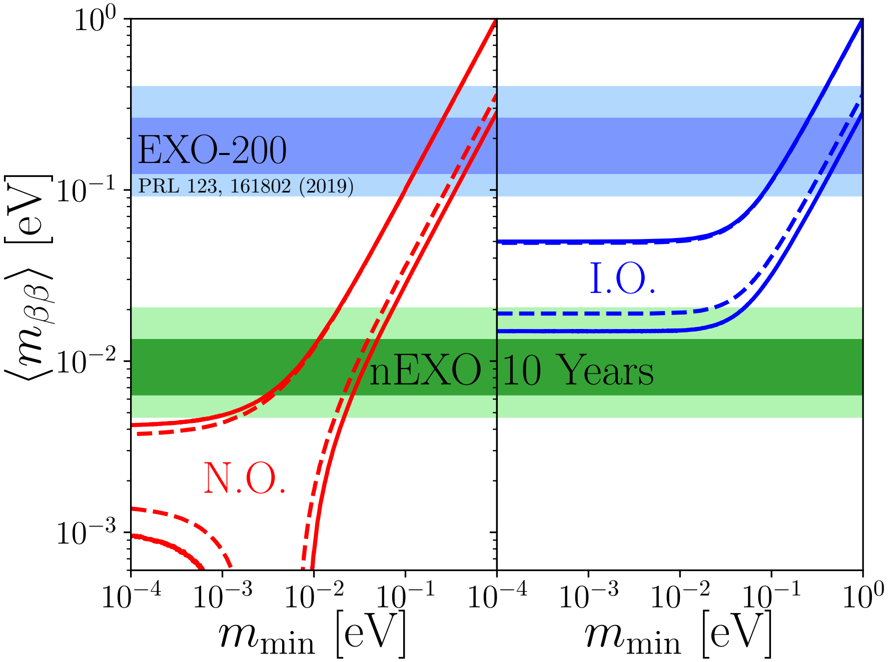
Sensitivities reported are median values over 5,000 toy experiments

- Can exclude $0\nu\beta\beta$ halflife of **1.35×10^{28} yrs at 90% CL**
- Can discover $0\nu\beta\beta$ halflife of **0.74×10^{28} yrs at 3σ significance**

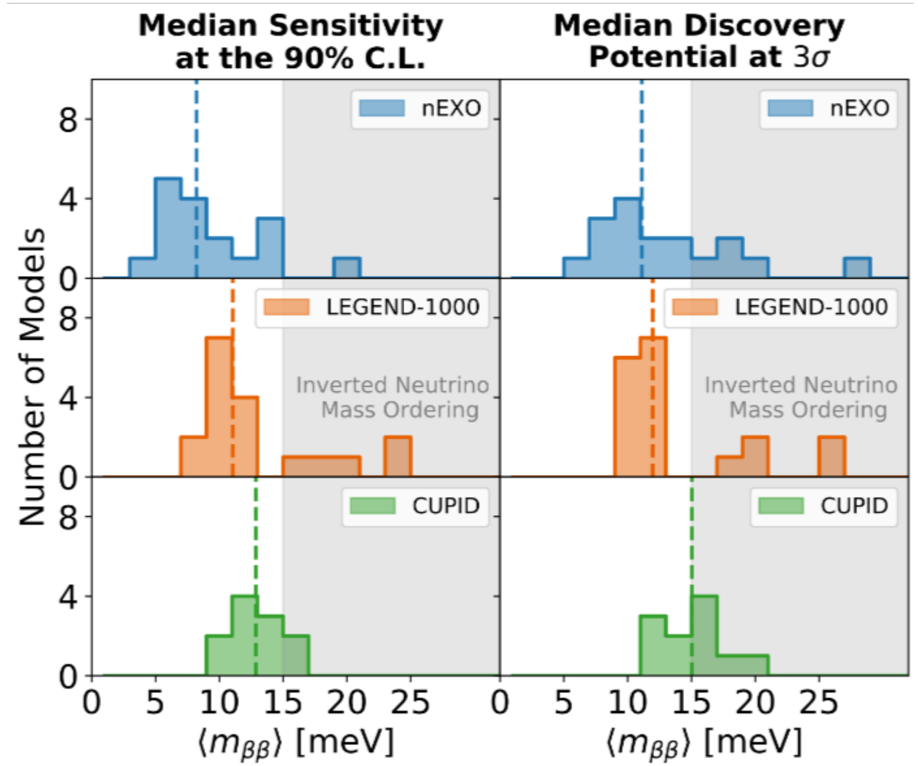
Adhikari et al., J. Phys. G 49 (2022), arXiv:2106.16243

Physics reach of nEXO

$$[T^{0\nu}_{1/2}]^{-1} = \frac{\langle m_{\beta\beta}\rangle^2}{m_e^2} G^{0\nu} |\mathcal{M}^{0\nu}|^2$$



Note: NMEs are not statistical…there is only one correct value. But calculations are challenging.



- **nEXO completely explores the inverted mass ordering in almost all cases.**
- **Sensitivity to Majorana neutrino mass: $m_{\beta\beta} \approx$ 4.7 – 20.3 meV.**

Summary

- **nEXO will search for 0νββ with a 5-ton liquid xenon time projection chamber.**
- **The projected sensitivity to ^{136}Xe 0νββ halflife is 1.35×10^{28} yrs at 90% CL , nearly 2 orders of magnitude improvement compared to current limits.**
- **Sensitivity to Majorana neutrino mass of 4.7 – 20.3 meV, covering the entire inverted neutrino mass ordering.**

For further details, see arXiv:2106.16243.


Mike Heffner
Seth Thibado
nEXO
Collaboration Meeting Dec 2020